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K. K. Aggarwal

Avinash C. Sharma

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Article

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K. K. Aggarwal

Avinash C. Sharma

Abstract

Industry 4.0 is coming to India very rapidly. . Adjusting to the rapidly changing global scenario, India, as a nation has to respond as fast as possible. Keeping in view, the diverse nature of country's demography, limited resources and political compulsions, Higher Education is one of the major and effective tools to bring in the requisite changes. The paper analyses the interaction of Higher Education with emerging trends in Industrial Revolution 4.0, and presents some implementable conclusions and a few game-changing recommendations.

The formal education-ecosystem is transformative in nature and all through ages has played a vital role in the development of society and nation's prosperity and growth. One of the core aims of the education system has been to address evolving needs of society and of the nation; on the other hand, the political, economic and technological developments have impacted and many a times, dictated the focus, the mode of delivery and the outcomes of the education system. Today, the sources of knowledge are global and hence the term Education 4.0[1] is about preparing students for future leadership positions in a globalised knowledge society. Education institutions and regulatory framework have to embrace Education 4.0 technologies and processes at a much faster pace than it did more than three decades ago when computer education came to India. This paper highlights a roadmap that higher education institutions, policymakers and regulators could adopt in order to adapt to this change.

1. K.K.Aggarwal, Founder Vice Chancellor, GGS Indraprastha University, New Delhi; presently, Chairman, NBA, MHRD

2. Avinash C. Sharma, Professor of Physics, GGS Indraprastha University, New Delhi

Higher education has a symbiotic relationship with the society at large. The society and economic considerations have been impacting the way the education system has evolved, while the education system provides knowledge and manpower to society. The landscape for education has changed across ages. In short, the stages of evolution are :

Education 1.0 (Guru-Shishya method of teaching in small groups), Education 2.0 (massification of education with the teacher as the knowledge provider and the student as the passive recipient), Education 3.0 (use of computers and internet in teaching and learning, accelerated the pace followed by Education 4.0 (high-speed internet, mobile technology, social media platforms, etc., facilitating personalized learning anytime anywhere and changing the role of teachers to facilitators and mentors).

The Industry 4.0 Ecosystem

Industry 4.0[2] (or the fourth industrial revolution) is a term given to the current trend of automation and developmental process in the management of manufacturing and chain production. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing. The term "Industry 4.0", shortened to I4.0 or simply I4, originates from a project in the high-tech strategy of the German government, which promotes the computerization of manufacturing.[3]In October 2012 the Working Group on Industry 4.0 presented a set of Industry 4.0 recommendations to the German federal government. The members of the working group are recognized as the founding fathers and driving force behind Industry 4.0. At the Hannover Fair on 8 April 2013, the final report of the Working Group Industry 4.0 was presented.[4] This working group was headed by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (German Academy of Science and Engineering).The German federal government adopted the idea in its High-Tech Strategy for 2020 and also formed a Working Group to further advice on the implementation of Industry 4.0.

In the evolution of modern industrialisation , the major peaks (that can be called 'revolution') are as follows:

The First Industrial Revolution

The industrial revolution in Britain was ushered in as machines were introduced into production in the 18th century (1760-1840). This included moving from manual production to the use of steam-powered engines and water generated power. This helped agriculture greatly and the term "factory" became a little popular. One of the industries that benefited a lot from such changes is the textile industry, and was the first to adopt these new methods. It also constituted a large part of the British economy of the time.

The Second Industrial Revolution

The second IR dates between 1870 and 1914 (although some of its characteristics date back to the 1850s) and linked telegraphs and railroads to industries. Perhaps the defining characteristic of that period was the introduction of mass production as a primary method of production in general. The electrification of factories accelerated the production rates. The mass production of steel helped introduce railways into the system, which consequently contributed to mass production. Innovations in chemistry, such as the invention of the synthetic dye, also made a mark in this period.

The Third Industrial Revolution

Most people living today are familiar with the third IR when industries became heavily dependent on digital technologies. Broadly, the start of third industrial revolution is dated between 1950 and 1970 and is often referred to as the Digital Revolution and many a times as the Information Age . This brought about the change from analog and mechanical systems to digital ones. The third revolution was, and still is, a direct result of the extraordinary development in computers and information and communication technology.

The fourth industrial revolution

Formally, the fourth industrial revolution takes the automation of manufacturing processes to a new level by introducing customised and flexible mass production technologies. This implies that machines will operate independently, or cooperate with humans in creating a customer-oriented production field that constantly works on maintaining itself. The machine rather becomes an independent entity that is able to collect data, analyse it, and advise upon it. This becomes possible by introducing self-optimisation, self-cognition, and self-customisation into the industry. The manufacturers will be able to communicate with computers rather than operate them manually.

Design principles

There are four design principles in Industry 4.0. These principles guides the enterprises companies in identifying and implementing Industry 4.0 scenarios.[5]

- Interconnection: The ability of machines, devices, sensors, and people to connect and communicate with each other via the Internet of Things (IoT) or the Internet of People (IoP).

- Information transparency: The transparency afforded by Industry 4.0 technology provides operators with vast amounts of useful information needed to make appropriate decisions. Interconnectivity allows operators to collect immense amounts of data and information from all points in the manufacturing process, thus aiding functionality and identifying key areas that can benefit from innovation and improvement.[6]
- Technical assistance: First, the ability of assistance systems to support humans by aggregating and visualizsing information comprehensively for making informed decisions and solving urgent problems on short notice. Second, the ability of cyber physical systems to support humans by conducting a range of tasks which are unpleasant, too exhausting, or unsafe for their them. human co-workers.
- Decentralised decisions: The ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomously as possible. Only in the case of exceptions, interferences, or conflicting goals, are tasks delegated to a higher level.

All through the ages, education has been evolving in response to the changes in society – the changes that are in turn driven by the evolving education system. Changing social paradigms and environment have transformed students' motivation and career expectations, emphasizing the need for comprehensive and effective education ecosystems. Additionally, higher education (HE) systems have evolved due to social, economic and demographic, political and technological changes. World-over, HE has been the privilege of a few till now. Globally, less than 50% of the people coming out of the school education system get into the HE ecosystem. There has been clearly a mismatch beytween the needs and expectations of many learners and the design of the HE system.

Although the HE ecosystem interacts with all the components of societal development and growth of a nation, in the present review-cum-analysis, we focus on the relationship between HE 4.0 and IR 4.0 and how they mutually affect and impact each other. In Section 2, we discuss various aspects and dynamics of two-way interactions between IR and HE. We present a perspective landscape of demographics of work-force of future India in the backdrop of IR 4.0 and the challenges this throws to HE 4.0. Section 3 discusses the Indian perspective of the strategies and envisioned growth of HE 4.0 to remain in tune with IR 4.0 requirements& expectations and challenges thereof; as well as with other societal developmental parameters impacted by IR 4.0 wherein HE can play a vital role. Also discussed is the vision of HE 4.0 as an emerging industrial sector in itself. The last Section 4 summarizes the major conclusions and some recommendations.

Demographics of future work-force & education ecosystem

The characteristics identified for the German government's Industry 4.0 strategy are: the strong customisation of products under the conditions of highly flexible (mass-) production.[7] The required automation technology is improved by the introduction of methods of self-optimisation, self-configuration[8] self-diagnosis, cognition and intelligent support of workers in their increasingly complex work.[9]

In June 2013, consultancy firm McKinsey[10] released an interview featuring an expert discussion between executives at Robert Bosch - Siegfried Dais (Partner of the Robert Bosch Industrietreuhand KG) and Heinz Derenbach (CEO of Bosch Software Innovations GmbH) - and McKinsey experts. This interview addressed the prevalence of the *Internet of Things* in manufacturing and the consequent technology-driven changes which promise to trigger a new industrial revolution. The basic principle of Industry 4.0 is that by connecting machines, work pieces and systems, businesses are creating intelligent networks along the entire value chain that can control each other autonomously. Some examples for Industry 4.0 are machines which can predict failures and trigger maintenance processes autonomously or self-organized logistics which react to unexpected changes in production.

According to Dais, "it is highly likely that the world of production will become more and more networked until everything is interlinked with everything else". While this sounds like a fair assumption and the driving force behind the Internet of Things, it also implies that the complexity of production and supplier networks will grow enormously. Networks and processes have so far mostly been limited to one factory. But in an Industry 4.0 scenario, these boundaries of individual factories will most likely no longer exist. Instead, they will be lifted in order to interconnect multiple factories or even across far geographical regions.

There are differences between a typical traditional factory and an Industry 4.0 factory. In the current industry environment, providing high-end quality service or product with the least cost is the key to success and industrial factories are trying to achieve as much performance as possible to increase their profit as well as enhance their reputation. In this way, various data sources are available to provide worthwhile information about different aspects of the factory. In this stage, the utilisation of data for understanding current operating conditions and detecting faults and failures is an important topic to research. e.g. in production, there are various commercial tools available to provide overall equipment effectiveness (OEE) information to factory management in order to highlight the root causes of problems and possible faults in the system. In contrast, in an Industry 4.0 factory, in addition to condition monitoring and fault diagnosis, components and systems are able to gain self-awareness and self-predictiveness, which will provide management with more insight on the status of the factory. Furthermore, peer-to-peer comparison and fusion of health information from various components provides a precise health prediction in component and system levels and force factory management to trigger required maintenance at the best possible time to reach just-in-time maintenance and gain near-zero downtime.[11]

During Open Innovation conducted in Oct 2018 at Lisbon, Portugal, Industry 4.0 conceptualisation was extended by Sensfix B.V. a Dutch company with introduction of M2S terminology. It essentially is characterising upcoming service industry to cater to millions of machines, managed by the machines themselves, using Artificial intelligence developed by humans!

Challenges [12]:

Some of the expected challenges offered by the Industry 4.0 can be listed as follows:

- IT security issues, which are greatly aggravated by the inherent need to open up those previously closed production shops
- Reliability and stability needed for critical machine-to-machine communication (M2M), including very short and stable latency times
- Need to maintain the integrity of production processes
- Need to avoid any IT snags, as those would cause expensive production outages
- Need to protect industrial know how (contained also in the control files for the industrial automation gear)
- Lack of adequate skill-sets to expedite the march towards fourth industrial revolution
- Threat of redundancy of the corporate IT department
- General reluctance to change by stakeholders
- Loss of many jobs to automatic processes and IT-controlled processes, especially for lesser educated parts of society
- Low commitment of the top management

- Unclear legal issues and data security
- Unclear economic benefits mainly because of excessive investment
- Lack of regulation, standards and forms of certifications
- Insufficient qualification and skills of employees

Role of big data and analytics

Modern information and communication technologies like cyber-physical systems, big data analytics and cloud computing, is expected to help early detection of defects and production failures, thus enabling their prevention and increasing productivity, quality, and agility benefits that have significant competitive value. Big data analytics consists of following 6Cs in the integrated Industry 4.0 and cyber physical systems environment.

1. Connection (sensor and networks)
2. Cloud (computing and data on demand)
3. Cyber (model & memory)
4. Content/context (meaning and correlation)
5. Community (sharing & collaboration)
6. Customization (personalisation and value)

In this scenario and in order to provide useful insight to the factory management, data has to be processed with advanced tools (analytics and algorithms) to generate meaningful information. Considering the presence of visible and invisible issues in an industrial factory, the information generation algorithm has to be capable of detecting and addressing invisible issues such as machine degradation, component wear, etc. in the factory floor.[13]

Technology Road map for Industry 4.0

A "road map" enables whomsoever in industry to directly realize each move and what acts need to be accomplished, who needs to make them and when. This method is decoded into a project plan, defining the characteristics of activity in each of the accompanying stages of formation. Considering an internationalized world, the need to actualize development strategies that can secure the sustainable competitiveness of establishments is the main issue. It is here that Industry 4.0 road map grants itself as a visually pictured clear trail to boost the competitiveness of organizations. The key benefits of technology road mapping are :

- Setting up coalition of technical and commercial master plans
- Making better communication across teams and companies
- Inspecting prospective competitive strategies and ways to carry out those strategies
- Competent time management and mapping out
- Conceptualizing outputs including goals, activities, and progresses.[14]

The Future Workforce

Industry 4.0 has a lot to promise when it comes to revenues, investment, and technological advancements, but employment still remains one of the most mysterious aspects of the new industrial revolution. It is even harder to quantify or estimate the potential employment scenerio.

What kind of new jobs will it introduce? What does a Smart Factory worker needs to have to be able to compete in an ever changing environment such as this? Will such changes lay off many workers? All of these are valid and highly relevant questions to any average worker. While it still remains early to speculate on employment conditions with the adoption of Industry 4.0 globally, it can be safely said that workers surely will need to acquire different or an all-new set of skills. This may help employment rates go up but it will also alienate a big sector workers. For example, the sector of workers whose work is perhaps repetitive will face a challenge in keeping up with the industry.

An article published in February 2016 strongly suggests that Industry 4.0 may have a beneficial effects for emerging economies such as India.[15] Given the nature of the industry, it will introduce new jobs in big data analysis[16], robot experts, and a huge number of mechanical engineers. In an attempt to determine the type of jobs that Industry 4.0 will introduce or need more labour in, BCG has published a report based on interviews with 20 of the industry's experts to showcase how 10 of the most essential use cases for the foundation of the industry will be affected .

The following are some of the important changes that will affect the demographics of employment[17]:

- **Big-Data-Driven Quality Control**: In engineering terms, quality control aims at reducing the inevitable variation between products. Quality Control depends to a large extent on statistical methods to show whether a specific feature of a product (such as size or weight) is changing in a way that can be considered a pattern. Of course such a process depends largely on collecting real-time or historical data regarding the product. However, since Industry 4.0 will rely on big data for that, the need for quality control workers will decrease. On the other side, the demand for big data scientists will increase.

- **Robot-Assisted Production**: The entire basis of the new industry is the capability of the smart devices being able to interact with the surrounding environment. This means that workers who assist in production (such as packaging) will be replaced with smart devices equipped with cameras, sensors, and actuators that are able to identify the product and then deliver the necessary changes for it. Consequently, the demand for such workers will fall and will be replaced with "robot coordinators".
- **Self-Driving Logistics Vehicles**: One of the most important focuses of optimisation is transportation. Engineers use linear programming methods (such as the Transportation Model) to optimally utilize the transportation. However, with self-driven vehicles, and with the assistance of big data, so many drivers will be laid off. In addition, having self-driven vehicles allows for restriction-free working hours and higher utility.
- **Production Line Simulation**: While the need for optimisation for transportation declines, the need for industrial engineers (who typically work on optimization and simulation) to simulate productions lines will increase. Having the technology to simulate production lines before establishment will open up jobs for mechanical engineers specializing in the industrial field.
- **Predictive Maintenance:** Having smart devices will allow manufacturers to predict failures. Smart machines will also be able to independently maintain themselves. Consequently, the number of traditional maintenance technicians will drop, and shall be replaced with more technically sound and informed ones.
- **Machines as a Service**: The new industry will also allow manufactures to sell a machine as a service. This means that instead of selling the entire machine to the client, the machine will be set-up and maintained by the manufacturer while the client takes advantage of the services it provides. This will open up jobs in maintenance and will require an expansion in sales.

Interfacing with Higher Education (HE 4.0)

Industry 4.0 is a convergence of disruptive digital technologies that are set to change the manufacturing sector beyond imagination driven by astonishing rise of data volumes, system integrations and connectivity, emergence of advanced analytics and business intelligence, capabilities, machine learnings, improvements in the transfer of digital instructions to the real world. The IR 4.0 provides a new impetus to educational transformation. In recent years, education experts recognise the profound impact that a myriad of technological innovations in ICT is having on education. It is generally agreed upon that Education 4.0 will be primarily shaped by innovations and thus will indeed have to have a focus that prepares students to produce innovations.

The picture of IR 4.0 is still quite fuzzy and it is difficult to definitely predict what lies ahead. Like the industrial revolutions in the past, IR 4.0 is expected to seriously affect the landscape of work-force and will create new jobs, and will also eliminate some of the existing jobs. It is predicted that routine activities including monitoring will be entirely or partly taken over by machines. For example, IBM Watson has developed AI-based expert system that can replace junior lawyers. AI system has also been developed, having potential to replace basic-level medical practitioners. This may mean fewer jobs for entry -level professionals in these areas, specialist jobs may remain though (may increase also).

In this context, it is important to impart appropriate education (the term 'education' in this paper includes the requisite mindset, knowledge and skills to the future workforce. Based on the trends so far, researchers predict that IR 4.0 will necessitate profound changes in major aspects of education: content, delivery/pedagogy, and structure/management of education. IR 4.0 demands changes in the contents of not only technical education, but also education in general. Across disciplines, new emphasis will have to be infused on certain skills and new contents have to be added. New educational programmes will have to be developed to meet changing demands.

Education Structure and Management

Industry 4.0 will see profound changes in business and governance models across the sectors. To cope with the shorter cycles of disruptive changes, one has to make lifelong learning a permanent part of professional life. This may, in turn, need new ways of recognizing and certifying work-place based learning. This will demand new modes of partnership between educational institution and industrial sector. Some experts suggest that there will be a need for compressed undergraduate study programmes, supplemented by practice and subsequent in-depth studies. Some even tend to suggest that fixed degree programmes, as we know today, may not be effective.

Universities, therefore, will need to re-think the way academic programmes will be structured in the future. To recognize more flexible, practice-oriented, competency based learning, new systems of accreditation/certification will be necessary. Application of big data analytics in teaching and learning will shape future adoptive learning environment. Research in Austria (TU Graz) has shown[i] that learning analytics can help teachers to see the success and failure of each student on each topic, provide them with early warning of knowledge gaps, and help them to take appropriate measures. These measures include use of automatic exercise generators that can give appropriate exercise to each student depending on his progress. Use of data analytics for monitoring progress and effectiveness in education will become commonplace.

To respond to the needs of IR 4.0, universities must continue to play their role as test beds for educating the future generation and innovation. But close collaboration with industry and stakeholders will be ever more important to implement Education 4.0. To be effective and efficient in such efforts, it will be important to have technology roadmaps for the main economic /industrial sectors of the country. Such technology roadmaps will provide the direction for the educational transformation which may have two main components: transform education across disciplines in terms of content, delivery, management, and devise special education/degree programmes to develop appropriate manpower to support Industry 4.0. Many of the core technical subjects being taught in various universities under different programmes needs to be revisited in the context of demanding requirements of IR 4.0 so as to find how the delivery of soft skills can be made more effective. In addition to soft skills, efforts should have to be made on how to make digital/data literacy more accessible to the general student mass across all disciplines. The need for human resources in the key technical areas like IoT, big data and analytics, cloud computing, virtual/augmented reality, robotics, etc. should be assessed and acted upon appropriately.

New interdisciplinary programmes need to be developed to cater to the future requirement. As a first step, pilot programmes may be developed to cater to a certain sectors that will be most influenced by IR 4.0.The manufacturing sector can be targeted to begin with. As introduction of out-of-the-box ideas for first degree may take time, a master programme in manufacturing that responds to the need of IR 4.0 can be developed as a first step. It has to be made interdisciplinary combining science, engineering, ICT and business studies. It can even be a multi-university project to bring the best of the nation on a common platform. Effective use of digital tools, maker space, LF, etc. should be made. Experts predict that IR 4.0 will be a long journey reaching maturity by 2025-2030.[ii] The educational institutions including universities need to break away from the process driven, technology supported mass teaching systems to a new

i. See References 1-3.

ii. See References 1-3.

way of education that appreciates and provides enough room for the personalization of learning. Flexible learning paths, focus on imparting life skills, student centric learning methods and extensive use of technology are leading us to the concept of "Education 4.0". We are again at the cusp of a change where the learner will be at the center of the future ecosystem in Education 4.0.

Research Ecosystem

Research has been one of the cornerstones of any university/ HE systems worldwide. A large amount of funding and intellectual time and energy is spent on promoting research – both academic and applied. The existing process of knowledge creation and research at universities has not integrated with the industry needs. However, still in many of the education systems around the world, some common elements have remained unchanged for many years.

- Research is often "inquisition driven" by the researcher, and is delinked to the "need", thus resulting in a lot of academic research and very limited applied research. A lot of this is also driven by design – Faculty and researchers are tenured and promoted based on the number of papers published than the practical impact. This in turn is driven by the various rankings of global universities that are swayed by the number of research papers. The research thus is used for credentialing the researcher and the institute, than creating real world impact.
- Research ecosystems have traditionally been rigid with research being driven by academic rigor rather than real problem solving. A PhD has multiple years of in class-teaching systems, and a stringent mechanism of problem definition, data collection and thesis writing than providing flexibility in rerouting and restarting as needed when changing situations & time demands.
- **Long time lags between research outputs from university and commercial outcomes.**
- The time span between university research outputs and its commercial usefulness/ utilization is too long, which makes a lot of innovations obsolete in today's dynamic environment even before they become commercially available.

Emergence of Education 4.0 in India and level of preparedness

Industry 4.0 fosters what has been named as "smart factory". Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time both internally and across organisational services offered and used by participants of the value chain.Broadly speaking, the Higher Education has to accept the growing demand for certifications and diplomas for vocational courses, prevalence of distance education, possibility of quick credentials or qualifications and the concept of classroom taking a backseat are likely to hit the formal culture of time-based degrees.

While education delivery has evolved over the ages all through Education 1.0 to Education 3.0 – the core process of teaching has remained almost constant. A teacher-instructed classroom has been the way knowledge is disseminated. From E2 until very recent past, i.e., pre-HE4.0 the content has been prepared in a more and more fixed curriculum structure, delivered at a point of time to the learner cohort and have gradually got standardized in terms of the content and its delivery. The "innovations" of respective ages such as the post, radio or television have done little to change the core concept of this teaching philosophy. It is only the speed and space that have changed. The HE system in Education 4.0 will focus on the learner, supported by technology, in-person guidance and industry-relevant content to meet the learner's individual learning needs.

In a recent report "*Higher Education in India : Vision 2030*", FICCI had categorised HEIs across India into the below-mentioned categories. These different types of institutions have fundamentally different focus and outcomes and are at present at different levels of preparedness to address the challenges of Education 4.0

Higher Education in India: Vision 2030

Category	Focus
Research-focused institutions	• High-quality institutions with research and innovation as the prime focus • Critical role in addressing intellectual imperatives
Career-focused institutions	• Institutions offering professional courses, with a focus on producing industry-ready graduates • Critical role in addressing economic imperatives
Foundation institutions	• Institutions offering a wide range of courses aimed at providing a well-rounded and holistic education • Imparting skills that are relevant to the local industry/ community • Critical role in addressing social imperatives

Source: FICCI

With increasing democratisation of knowledge, research-focused institutions would need to change the "ways of doing" research. Universities need to focus on conducting applied research that can create real world impact. They need to utilise technology at all stages of research to reduce the time span between university research outputs and commercial outcomes.

This transition from one paradigm to the other is uneven, and how fast universities adapt to this change and continue to evolve will determine their future. With the changing paradigm, universities have a critical decision to make: Embrace new opportunities and succeed or make the wrong choice and perish? It is crucial for universities to focus on enriching student experience, aligning to individual needs across the student life cycle, focusing on student employability and acting as a hub for research.

- Universities could focus on building unrivalled student experience through flexible programme structures that enable lifelong learning and provide learners with multiple entry and exit options. They could provide learners with predictable schedules and opportunities for collaborative learning.
- Universities will have to address employability challenges by providing the required employability skills and integrating with industry to provide greater exposure to students right through their university experience. They need to enable development of thinkers, complex problem solvers and decision makers who are prepared for a broad range of jobs across sectors and thus can be fungible across changing job scenarios.
- Global integration and technological advancement have had a transformational effect on research not only in terms of focus but also the way it is conducted (the process of its conduct). As research becomes democratised, funds would need to be spent in the most optimal manner. Universities need to build project management capabilities around research to ensure quick turnarounds, reduce cost and schedule overruns and better & effective collaborations across industry and academia.
- Universities with weak financial statements could pass this financial burden to the student in form of rising tuition fees, but the price-sensitive student is now turning to alternative affordable education sources such as massive open online courses (MOOCs). Universities will need to diversify their revenue stream and explore sustainable business models to continue operations. They will have to ensure that resources are optimally aligned with financial stability at the core.
- Regulators need to appreciate "online" as a viable medium of learning. They would have to provide a forward-looking ecosystem for Education 4.0 and work with higher education institutions (HEIs) on developing new regulatory frameworks that

encourages a culture of innovation & creativity, and also addresses issues of quality control, accreditation and information privacy.

HE 4.0 for IR 4.0

The core mission of higher education remains the same whatever the era. The goal of higher education is to ensure quality of learning via teaching to enable the students to gather latest knowledge through exploratory research, and to sustain the development of societies by means of service.

- **Teaching:**

  One of the principal tasks of every university is to educate the youth. Therefore, it is necessary to implement appropriate teaching strategies and to organise work in a way that fosters learning. This has implications on adaptable learning programmes, better learning experience, and lifelong learning attitude.

- **Research:**

  The journey towards global competition in the higher education requires institutions to put a huge amount of effort into research and development (R&D). Experts believe these forces range from new technology deployment to global cooperation and collaboration.

- **Service :**

  To sustain the competitive position among world higher education system, we need to radically improve educational services. In particular, it will be necessary to bring much greater innovation, and competition into education.

The changing skill requirements from the industry demands a competency-based learning model than a fixed and rigid learning structure.

Competency-based learning is aimed at mastering skills/ knowledge regardless of the time it takes. It promotes self-paced learning and caters to students across various levels of learning.[iii]

65%	**% of jobs at risk of automation by 2030**	**74%**
of children joining a primary school in 2016 will eventually end up working in a completely new job that does not even exist today.	US 38% UK 30% Germany 35% Japan 21%	of the surveyed employees are ready to acquire new skills and completely retrain in order be relevant and remain employable in the future.

iii. See Reference 1.

Hence, competency-based methodologies offer students with greater opportunities for deep and personalised learning, as students have to work toward achieving competency at their own pace, which subsequently demands increased individual support and greater autonomy.

What does the non-traditional student demand?

- Affordable learning solutions with a quick return on investment.
- Courses offering flexibility and multidisciplinary options.
- Course availability in multiple formats and days/ times.
- Career counselling support – Getting a better job is their top objective.
- Clear proactive communication/ information about services offered.

Convergence of HE with Technology

Challenges faced by Universities	Cohort learning Fixed education structure Single pace of learning	Face-to-face knowledge dissemination Limited counselling system	Knowledge based in physical libraries, making it the exclusive domain of the university
Need for HE solutions	Emphasis on personalized and adaptive learning and cognitive flexibility to tailor education needs	Focus on differentiated instruction to help teachers assess students interests and strengths	Self-learning encouraging critical thinking and proactive approach of learning for students
New Technologies for improvising HE	Use of LMS and ERP solutions allowing customized user interface for every user	Online assessment and data analysis are enabling teachers in understanding student performances	Omni-present knowledge through internet enabling increasing demand for distance learning courses

Global universities would have to reformulate their strategies across all the levels to remain relevant for Education 4.0. The Education 4.0 puts the learner at the center of the ecosystem and empowers him or her to structure individual paths keeping in mind the final outcome. Universities need to provide unrivalled student experience and be at forefront of knowledge creation to remain relevant. HEIs need to respect complexities and variances in learner behavior and move away from cohort-based classes and change/ extent the role of a teacher from that of a mere instructor to a facilitator and coach.

Degrees and other credentials have been one of the most visible and tangible outputs of the university system. These credentials, however, are under threat, with the underlying learning losing its touch with the needs of the industry and society. The online revolution is further challenging this citadel of higher education. Micro credentials and badges from the MOOC platforms are being more acceptable in the industry and the informal job market. Universities have to focus primarily on knowledge creation through research in a timely and cost effective manner. They need to provide unrivalled student experience and be at forefront of knowledge creation to remain relevant in the age of Education 4.0.Universities would need to focus on collaborative ways of learning and build flexible programme structures that enable lifelong learning and provide learners with multiple entry and exit options. They further need to provide learners with predictable schedules and personalised learning paths suited to their level of competency. Some of the requisite characteristics are:

- Flexible programme structures
- Peer-to-peer learning
- Lifelong learning
- Blended learning
- Use of analytics
- Flexible predictable schedules
- Adaptive learning

Furthermore, the universities need to strive to be the nucleus for all research collaborations in academia and industry and look at alternate sources of funding for their innovations and harness their potential by developing innovative enrollment models that utilize its resources optimally. Regulators would have to provide the framework for an interoperable and equitable ecosystem for the personalised choices of the learner while working toward developing talent and capabilities in addressing Education 4.0

- Develop skills of teachers, administrators and institution leaders
- Encourage collaborations in multi-disciplinary and impact research

Curricula and pedagogy

- Design curriculum with strong linkages and exposure to real world learning methods delivered as student experience and in class learning while the conceptual programme delivery is through blended/ online methods
- Develop flexible learning programmes with multiple entry and exit points
- Invest in technology-driven flexible curriculum feedback and redesign the model for real time learning validation and course correction suited to individual learner

- Recognise out-of-class learnings carried-out through certifications, work experience and experiential learning at the time of entry
- Develop blended learning models and advanced credit systems including credits for MOOC completions
- Integrate life skills into the curriculum through integration with real world stakeholders such as industry, society and entrepreneur networks
- Offer digital media-based collaboration and peer-to-peer learning tools as part of the curriculum, for social learning and life skill development

Partnerships

- Partner with industry and local society across all aspects of the education value chain from curricula and faculty to infrastructure, research, study experience and placements
- Develop curriculum, teaching, MOOCs and faculty partnerships with global universities to develop offerings for liberal curriculum programs
- Invest in professional development platforms that foster partnerships with individuals and alumni who could act as mentors and facilitators for industry-academia linkages
- Develop innovative models to partner with digital and social media platforms to enrich the learning process through peer and social learning methods
- Co-opt industry trainings and in situ programs that can be designed by industry and delivered by universities

Research

- Foster collaborative models with global experts from academia and industry for research
- Develop multi-disciplinary and applied research capabilities through adjunct and industry faculty tracks
- Promote universities as local community-focused centers of research with tight linkages with local industry and society in the region
- Other in-site joint research opportunity for small and medium enterprises with limited research infrastructure

Faculty

- Invest in faculty training focused toward developing facilitator mindset and pedagogy
- Develop continuing professional development (CPD) programs to support the development of digital literacy skills among academicians and staff
- Build a group of champion academicians coming from different departments who are leading the way in the development of digital skills or new innovative teaching techniques utilizing technology
- Train faculty for adopting technology as a medium of teaching design and delivery, including refresher training in trends such as flip classroom, synchronous video lecture and chat rooms
- Develop learning analytics solutions and facilitate faculty to use them for curriculum development and updating

HE 4.0 as an emerging "industry"

Apart from the formal Higher Education sector (both state-sponsored as well as privately managed) regulated by the state; the informal sector too is also expected to show a rapid growth as an independent industry providing flexible, customised industrial/ teaching/ training programmes with appropriate certifications, wherein there are no racial or age barriers. This industrial segment is expected to be highly innovative, demand driven and highly personalised both in terms of the deliverable as well as in terms of process. Some of such areas can be financial sector, science popularisation, developing scientific-temper among masses, tourism, hospitality, creative and performing arts, heritage studies, healthcare and legal service apart from IT based support services to all of these areas.

Open Innovation Environment

- Evolutionary & Revolutionary Innovations
- New Technological Advancement Driven Research and Development
- Shorten Innovation Cycles : Red Queen effect
- Education-as-a-Service (EaaS) – Cloud computing, amongst other techniques, creates a new way of educating people that might eventually disrupt the existing higher education systems. In Service 4.0, EaaS as a guide line has to discover newer and more advanced strategies to cope with ever-increasing societal complexity.

- Internationally-linked Programmes – With the fast pace of the fourth industrial revolution, forging various kinds of institutional linkages, both domestically and internationally, tooffer more versatile degree programmes and professional qualifications becomes a must.Among these schemes, the following types stand out and are worth consideration. First, twinning programmes where a local education provider collaborates with a foreign education provider to develop a connected system allowing course credits to be taken in different locations. On completion of the twining programme, foreign education provider awards a qualification. Second, franchise programmes is a scenario where foreign education provider authorizes a local education provider to deliver their courses/programmes, and the qualification is awarded by the foreign education provider. Third double or joint degree is an arrangement where local and foreign education providers cooperate to offer a programme for a qualification that is awarded jointly or from each of them. Fourth, blended learning where local and foreign education providers deliver programmes to enroll students in various mixed forms, e.g.,e-learning, online learning, or on-site learning.

Summary and conclusions

Indian and global universities, in fact the entire education ecosystem, have to recalibrate their strategies across all the levers for higher education to remain relevant in the age of Education 4.0. A paradigm shift is inevitable to cater to the needs to this growing target segment of non-traditional students. This new majority demands a greater deal of flexibility and customization, making personalized learning the preferred learning path.

Education 4.0 is the **personalisation** of the learning process, where the learner has complete flexibility to be the architect of his or her own learning path and has the freedom to **aspire for, approach and achieve** personal goals by choice.

Education 4.0 must address :

- Handling pressure to innovate new technologies
- Handling rapidly growing digital population by businesses and companies
- Developing new types of behaviour
- Developing new leadership and governance mechanisms
- Increasing numbers of products and options
- Shortened technology cycles

Some of the definitive recommendations are summarised below :

- Increase the GDP on education from 1% to 1.5%. Economics (analysis of cost and benefit) of higher education needs to be discussed in more details.
- STEM education to be made a national priority;
- Flexible governance system for institution of higher learning to make enough room for intense vertical and horizontal interactions among the experts both within and outside the organization.
- Need for a holistic and innovative use of technology for teaching-learning and research. Integration of reformative schemes like SWAYAM to larger teaching community. API (academic performance indicators) or any other metric used to assess teachers in HEI should also consider their participation in MOOCs and SWAYAM platforms.
- Developing and nurturing: Academic leadership possessing 'must have' attributes: vision, voice, professional integrity, ethical credibility and output driven (with emphasis on quality, knowledge creation, inventions and innovations).
- Serious efforts are warranted for improving science culture in education by recognising Science as a cultural & creative activity and allow time and space for growth of scientific temper. Bring a scientific temper to translate our strength of 'Jugad Culture' into 'Culture of Innovation'. Undergraduate teaching of science should include texts on history and philosophy of science- to reinforce creative nature of science. Observational projects must be introduced at school and at undergraduate level that require observation of natural phenomena and recording and analyzing those observations. Comparable weightage to field observations and classroom learning is desirable and the habit of pictorial thinking is to be developed.
- Serious efforts are required to move from a "*knowledge delivering system*" to "*knowledge creating system*". Following may be in order :
    - ♦ Work-out implementable strategies wherein traditional Indian systems of philosophy may be introduced at school and at undergraduate levels appropriately.
    - ♦ Develop a culture to understand and appreciate that Creativity is an important part of being. Let us start gradually bringing in a culture of creativity replacing the conformance.
    - ♦ The solutions to STEM Education cannot be just imported. An all out-of-box approach, suiting our own conditions & resources is needed.

- ♦ Recognise and work towards the fact that multiple intelligencies are to be inculcated in children for an ultimate creative and productive society.
- ♦ Inculcates the Scientific temperament which can develop their creative and entrepreneurial knowledge. It is to be appreciated that creativity in the class room leads to creativity in the Board room.

- There has to be a major component of '***Computational Thinking***' right from the School level till the Higher Education level.
- To prepare & nurture a group of teachers specially to implement creative science and engineering teaching; bring in changes in teaching pedagogy for inculcating Innovative strategies for instruction & assessment. There is strong need to develop Innovative learning aids for STEM Education. To develop, recruit and retain a pool of one lakh excellent quality STEM teachers.
- Introduction of B.Tech (vocational) in most conventional B Tech disciplines at a massive scale. The curriculum of these programmes (in various disciplines) be so designed so that there is clear cut dominance of skills based courses. Admission norms to B.Tech be made restrictive thus filtering of candidates for B.Tech (voc). There should, of course be enabling provisions for horizontal mobility between these two programmes in the first two years.
- Aligning engineering education with economy and society of the region. A comprehensive GIS (Geographical Information System) supported profile of the region and people to be used to introduce the programme. Curriculum to expose the students to the history, culture, industry and economy of the region. Also, linking programmes with organised industry (large and medium) of the region, to build close linkages with them for their requirement of manpower, skill development, upgradation, appropriate/ requisite R&D support, etc.
- Integrating skills into formal education system. Introduce the skill based courses to the vast list of available courses in the existing programmes and encourage all possible combination among the traditional courses with skill based courses.
- The universities which are awarding doctorate degrees in engineering streams will have to be monitored very carefully to avoid substandard Ph.D thesis. While increasing the number of Ph Ds in STEM areas is important, weeding out of poor quality thesis and linking the research to end users should be a priority.
- To substantially increase and sustain public and youth engagement with STEM and to improve the STEM-aesthetics experience among masses.

- Plan and establish national level specialised institutions in areas where impact is expected to be highest and long term. For example, Artificial Intelligence, Cyber security, Climate change, Event driven Business Ecosystem, IOT, etc.
- All institutes need to be sensitised to inculcate entrepreneurship among the STEM students, researchers and faculty too. They may be offered support by way of incubation centres, research barracks, mentoring, easy funding, infrastructure support, etc. They may also be linked-up with the business schools for marketing and project management related mentoring.
- In the last couple of decades quite a number of young researchers who learnt from abroad but could not gel with local ecosystem and went back – some of them were associated with high-end high precision technologies, others were with power science – risks being different. This warrants urgent attention and appropriate corrective measures to achieve an inviting research ecosystem.

In short, Indian Higher Education ecosystem has already started getting sensitized and gearing-up to face the expected challenges from the Fourth Industrial Revolution. Nevertheless, several intraventions to modify/ change existing ones and newer hard policy decisions are required to be taken for smooth shift towards Industry 4.0. Some of these steps have been identified in this paper.. Unless Education 4.0 really happens, Industry 4.0 will only remain a dream.

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